

## 4.0 DISCUSSION

A primary objective of this study was to assess water quality and the potentials for contaminant bioaccumulation associated with the 4H shell mounds. This was done by using caged mussels as a measure of potential bioaccumulation and concentration of contaminants from water, combined with quantitative comparisons of end-of-test tissue contaminant concentrations, to assess whether chemicals are leaching or are remobilized to the water column.

Results from the caged mussel bioassays demonstrated that there were no significant differences between the shell mound and reference sites in contaminant bioavailability. The high mussel survival rates, growth metrics, and significant increases in tissue lipid content (compared with the beginning-of-test mussels) further demonstrated that the test was successful and that the absence of significant spatial differences in contaminant bioaccumulation was not attributable to stressful exposure conditions or loss of lipids due to spawning or poor feeding conditions. Further, the analytical chemistry methods used were appropriately sensitive, and the level of replication provided adequate statistical power to detect differences among sites in tissue contaminant burdens. Based on these factors, the results of the bioassay are expected to accurately reflect an absence of any measurable difference in water quality conditions for the shell mound and reference sites.

Although bioaccumulation was the primary emphasis of the study, mussel survival and growth were also measured as indicators of mussel health. Mussel growth is commonly measured for three primary purposes: (1) as an effects endpoint; (2) to calibrate bioaccumulation; and (3) as a performance criterion to demonstrate that the test was successful (ASTM, 2001). The main reason for measuring growth in this particular study was to calibrate bioaccumulation and demonstrate a successful test. The caged mussel study was considered successful and the data were sufficiently rigorous to interpret bioavailability, as demonstrated by high mean survival and significant increases in length, WAWW, and tissue weights at all sites (except for tissue weights at the deep reference site).

The absence of significant contaminant bioaccumulation in caged mussels deployed at the shell mound sites was consistent with the general lack of significantly elevated contaminant concentrations in tissues of macroinvertebrates collected on and around the 4H shell mounds by MEC (2002). Whereas the shell mound core testing results obtained by AMEC (2002b) demonstrated significant bioaccumulation of metals and petroleum hydrocarbons (PAHs) by organisms exposed to mixed core sediments, macroinvertebrates feeding on or near the shell mounds are exposed only to the external surface materials and not the buried portions of the shell mounds that contain the highest concentrations of the contaminants, such as PCBs, with the greatest potential for bioaccumulation (i.e., with high partitioning coefficients). Relatively greater potentials for significant bioaccumulation by macroinvertebrates on the shell mounds would be expected if the contaminants were distributed uniformly within the mounds, including the mound surface.

The absence of enhanced contaminant bioavailability near the 4H shell mounds was consistent with the previous sediment core results of AMEC (2002b) and deWit (2001). In particular, chemical analyses of the shell mound cores performed by AMEC reflected the presence of elevated concentrations of some contaminant classes, such as alkyl benzenes and other lower molecular weight aromatic hydrocarbons, that typically are considered labile in the marine environment. Because of their high water solubilities, these compounds do not tend to persist in marine sediments, and their presence in the shell mounds indicated that diffusion and advection of contaminants with the mounds was negligible.

It is likely that the petroleum hydrocarbons, as well as barium, PCBs, and other less soluble contaminants that are present at elevated concentrations in the shell mounds, were originally associated with drilling muds and cuttings that were discharged from the platforms prior to the 1969-1976 moratorium on discharges of drilling wastes into State waters. Therefore, the present contaminant compositions and concentrations within the shell mounds probably have remained largely unchanged for more than 30 years. During this time, numerous high-energy storms have occurred in the area, especially during periods coinciding with El Niño events (e.g., 1970, 1973, 1975, 1988, and 1998). Similarly, a number of storm events of varying intensity occurred during the caged mussel bioassay study. There was no evidence from this study that these recent storm conditions caused or exacerbated contaminant remobilization from the shell mounds. Furthermore, the presence of appreciable amounts of labile contaminants in the shell mounds suggested that historical storm events did not substantially disrupt the integrity of the mounds and, in the absence of mechanical disturbances, these contaminants may persist in their present form.

The primary objective of the surficial sediment sampling and analysis task was to characterize sediment quality near each of the shell mounds and determine whether and to what extent the shell mound materials are similar to those of adjacent sediments. This is important for evaluating potential impacts from removal alternatives that involve in-place spreading of a mound(s). In general, the magnitude of any biological impacts related to in-place spreading are expected to be less severe if the physical and chemical characteristics of the shell mound materials are similar to those of the adjacent bottom sediments.

Some the textural (i.e., grain size) and chemical characteristics of the shell mound cores, as described by AMEC (2002b) and deWit (2001), were notably different from those of the bottom sediments near the mounds. The biggest differences were high proportions of gravel and sand-sized particles and elevated concentrations of selected metals (e.g., barium and zinc) and organic (PCBs and petroleum hydrocarbons) constituents. Other characteristics of the shell mound materials, such as total organic carbon and pesticide concentrations, were largely similar to those of the adjacent bottom sediments.

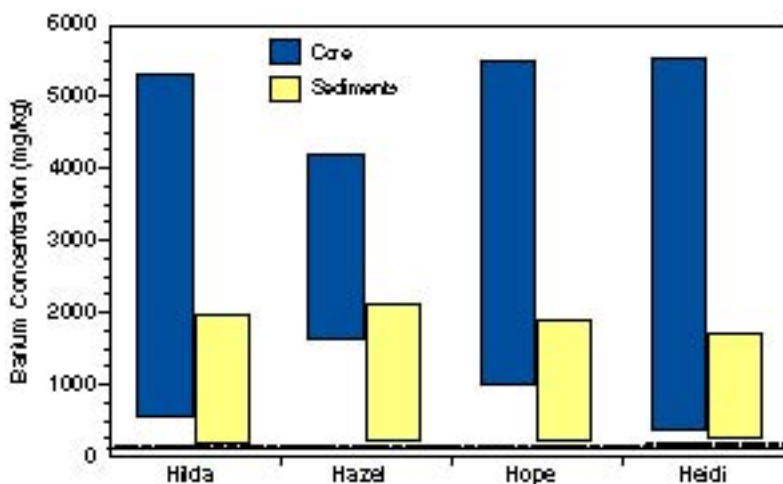
Composite samples of cores from each of the shell mounds, analyzed by AMEC (2002b) contained 16 to 28% gravel-sized particles and 11 to 42% sand-sized particles, whereas surface sediments near the mounds, analyzed during this study, contained 6 to

24% sands and no gravel-sized particles. The gravel-sized particles measured in the shell mound cores likely corresponded primarily to shell hash and cuttings particles. If the mounds were spread in-place, the shell hash materials would break into smaller pieces and eventually (months to years) decompose. In contrast, cuttings particles are considered relatively inert, and rapid decomposition or weathering would not be expected. Although gravel-sized particles were not observed in the present study, the distributions of barium concentrations in bottom sediments suggested that some pieces of the shell mounds have been dispersed from the base of the mounds, probably as a result of the platform removal operations, anchoring, or bottom trawling. Nevertheless, spreading in-place of the existing shell mounds would distribute cuttings particles over a proportionally larger footprint and would likely contribute to some localized heterogeneity in sediment texture.

Of the suite of shell mound core metals analyzed by AMEC (2002b), only barium, zinc, lead, chromium, nickel, and vanadium appeared to be enriched relative to background or reference concentrations. The maximum barium concentrations measured in the shell mound cores were approximately 5500 mg/kg, about 30 times higher than background concentrations (i.e., average concentrations for the Bight'98 stations). Thus, spreading in-place of the shell mounds could result in some increases within the footprint in the concentrations of sediment barium. Ranges in barium concentrations in shell mound cores, surface sediments near the shell mounds, and reference sediments are compared in Figure 4-1. Barium has a low acute toxicity and it is not substantially bioaccumulated by marine organisms, although testing by AMEC (2002b) observed that barium concentrations in tissues of clams and worms exposed to shell mound sediments were significantly higher than in reference samples. Regardless, a several-fold increase in sediment barium concentrations within the spreading footprint would not be expected to cause significant biological impacts. Concentrations of barium would be expected to decrease with time as the sediments are reworked by surface-dwelling organisms and the shell mound solids are diluted with more recently deposited sediments. This is consistent with the results from long-term monitoring programs evaluating the effects of waste discharges from offshore oil and gas platforms (e.g., Phillips et al., 1998). Maximum concentrations of zinc and lead in the shell mound cores were within factors of 7 and 11 times higher, while maximum concentrations of nickel and chromium were less than two and 4 times higher, respectively, than background concentrations (Figures 4-2 and 4-3). Because of the relatively small differences between concentrations of these metals in the shell mound materials and adjacent bottom sediments, it is unlikely that spreading-in-place would affect concentrations of these metals.

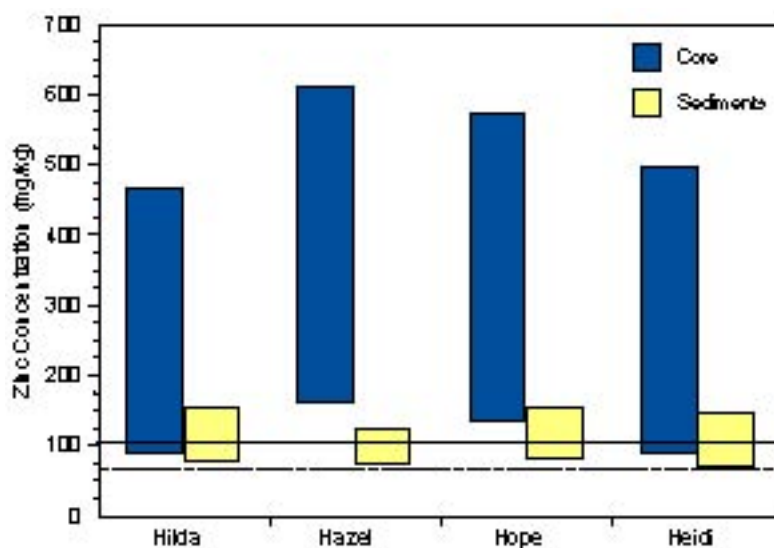
Three of the four shell mounds (Hazel, Hilda, and Hope) contained measurable PCB concentrations, and all mounds contained evidence of petroleum hydrocarbon contamination. As discussed in Section 3.4, bottom sediments near the Hazel, Hilda, and Hope shell mounds contained PCB concentrations that were elevated relative to reference and background levels, whereas PCBs near the Heidi shell mound were not detected. The ranges in PCB concentrations in shell mound cores, surface sediments near the shell mounds, and reference sediments are compared in Figure 4-4. Spreading in-place would add to the existing PCB concentrations in the bottom

sediments near the Hazel, Hilda, and Hope shell mounds, but not at the Heidi shell mound. Resulting concentrations could exceed levels at which biological effects may be expected (e.g., effects range-median value of 180 ng/g; Long et al., 1995). PCBs also have strong affinities for lipid materials and are not easily metabolized, which can promote bioaccumulation in marine organisms. Unlike PCBs, petroleum hydrocarbons would be expected to weather rapidly if the present integrity of the shell mound structures was disturbed. In particular, the low molecular weight mono- and dicyclic aromatic hydrocarbons (e.g., benzenes and naphthalenes) would dissolve in bottom waters and be rapidly diluted. Hydrocarbons also would be subject to microbial degradation. Losses due to weathering of the low molecular weight aromatic hydrocarbons would rapidly reduce potentials for acute toxicity. Residues of the more resistant higher molecular weight hydrocarbons could remain, although concentrations of these components eventually would decline in response to continued weathering and dilution. The extent of any sediment quality effects could depend in part on the degree of mixing and dilution with adjacent bottom sediments during spreading, deposition and mixing rates of new sediments, chemical and biological degradation or residual contaminants, and the spatial scale of the shell mound footprint.

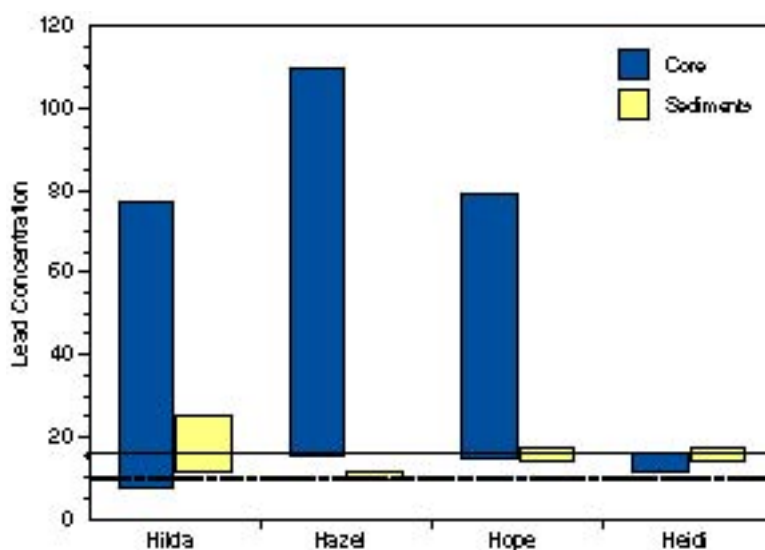


**Figure 4-1. Barium Concentrations (mg/kg) in Shell Mound Cores (Dark Boxes) and Bottom Sediments Adjacent to the Shell Mounds (Light Boxes)**

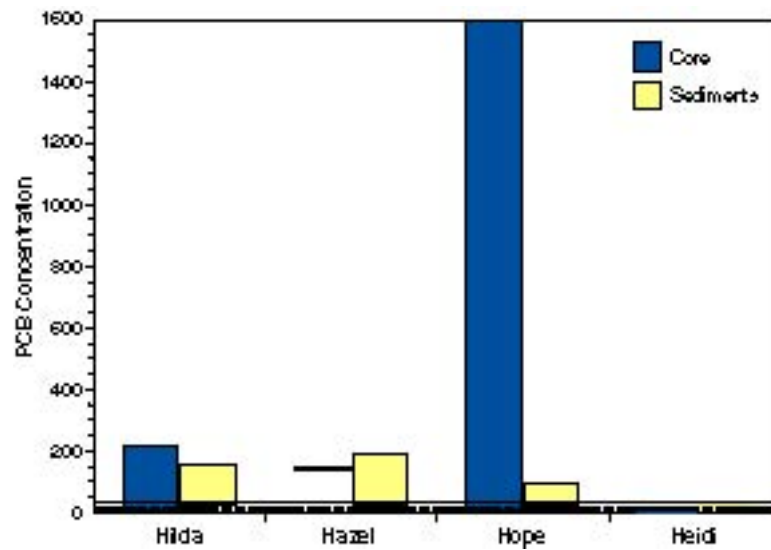
(Boxes represent the ranges in concentrations. The solid and dashed horizontal lines represent concentrations for the deep and shallow reference sites, respectively.)



**Figure 4-2. Zinc Concentrations (mg/kg) in Shell Mound Cores (Dark Boxes) and Bottom Sediments Adjacent to the Shell Mounds (Light Boxes)**  
(Boxes represent the ranges in concentrations. The solid and dashed horizontal lines represent concentrations for the deep and shallow reference sites, respectively.)



**Figure 4-3. Lead Concentrations (mg/kg) in Shell Mound Cores (Dark Boxes) and Bottom Sediments Adjacent to the Shell Mounds (Light Boxes)**  
(Boxes represent the ranges in concentrations. The solid and dashed horizontal lines represent concentrations for the deep and shallow reference sites, respectively.)



**Figure 4-4. PCB Concentrations (µg/kg) in Shell Mound Cores (Dark Boxes) and Bottom Sediments Adjacent to the Shell Mounds (Light Boxes)**  
(Boxes represent the ranges in concentrations. The solid and dashed horizontal lines represent concentrations for the deep and shallow reference sites, respectively.)